DESCRIPTION

ELECTRIC POTENTIAL MEASURING DEVICE USING

OSCILLATING DEVICE, IMAGE FORMING APPARATUS, AND

5   ELECTRIC POTENTIAL MEASURING METHOD

TECHNICAL FIELD

The present invention relates to an electric

potential measuring device using an oscillating

10   device, an image forming apparatus, and an electric

potential measuring method.

BACKGROUND ART

Conventionally, in an image forming apparatus of,

15   for example, the type which has a photosensitive drum

and forms an image by an electrophotographic process,

it is necessary to appropriately (typically,

uniformly) charge a photosensitive drum in any

environmental conditions, in order to always secure

20   stable image quality. To this end, charged potential

of the photosensitive drum is measured by using an

electric potential measuring device (electric

potential sensor), and a feedback control is carried

out by utilizing a result of the measurement so as to

25   secure uniform electric potential distribution over

the photosensitive drum.

For the conventional electric potential sensor,

a non-contact electric potential sensor is known, and especially, the electric potential sensor of the so-called mechanically modulated alternating electric field induction type is frequently used. In this type of potential sensor, electric potential on a surface of a measuring object is a function of the amplitude of current derived from a detection electrode contained in the potential sensor, and the current is mathematically expressed by the following equation:

$$i = dQ/dt = d[CV]/dt \ldots (1)$$

where Q is an amount of charge appearing on the detection electrode, C is a coupling capacitance between the detection electrode and the measuring object, and V is an electric potential on a surface of the measuring object. The coupling capacitance C is given by the following equation:

$$C = AS/x \ldots (2)$$

where A is a proportional constant, which includes the dielectric constant of material, S is an area of the detection electrode, and x is a distance between the detection electrode and the measuring object.

An electric potential V on a surface of the measuring object is measured by using the relation among those items. It is known that to exactly measure a charge amount Q appearing on the detection electrode, it is preferable to periodically modulate the magnitude of the capacitance C between the

detection electrode and the measuring object. The
following methods for modulating the magnitude of the
capacitance C are known.

A first modulating method is to effectively

5   modulate the area S of the detection electrode. As
for a typical example of this method, a fork-shaped
shutter is placed between the measuring object and
the detection electrode. The degree of shutting-off
of lines of electric force which reaches the

10 detection electrode from the measuring object is
varied by periodically moving the shutter in a
direction parallel to a surface of the measuring
object. In this way, the area of the detection
electrode is effectively varied to realize the

15 modulation of the capacitance C between the measuring
object and the detection electrode (see U.S. Patent
No. 4,720, 682).

In another example of the modulating method, a
shielding member with an aperture is disposed at a

20 place facing the measuring object. A detection
electrode is provided at a tip of a vibrating element
shaped like a fork. The detection electrode is
displaced just under the aperture in a direction
parallel to the measuring object. In this way, the

25 number of lines of electric force reaching the
detection electrode is modulated to thereby modulate
the capacitance C (see U.S. Patent No. 3,852,667).

A second modulating method is to periodically vary a distance x between the detection electrode and the measuring object. In a typical example of this method, a detection electrode is provided at a tip of a cantilever-like vibrating element. A distance X between the measuring object and the detection electrode is periodically varied by vibrating the cantilever-like vibrating element, whereby the capacitance C is modulated (see U.S. Patent No. 4,763,078).

Further, U.S. Patent No. 5,212,451 discloses an electrostatic measurement apparatus having a single balanced beam.

More specifically, it discloses the following apparatus. That is, there is disclosed an apparatus for measuring the magnitude of an electrostatic field, comprising:

a balanced beam vibratory element;

means for resiliently supporting said balanced beam vibratory element;

drive means for vibrating said balanced beam vibratory element; and an electrode, operatively associated with said balanced beam vibratory element, for sensing a capacitive coupling relationship with the electrostatic field and thereby producing a signal indicative of the magnitude of the electrostatic field during modulation of the coupling

relationship.

In the technical circumstances as stated above, recently, with the trend of reduction of the photosensitive drum diameter and increase of the

5   density of the arrangement of related components disposed around the photosensitive drum, the size reduction and the thinning of the electric potential sensor are required. In the currently used potential sensor of the mechanically modulated alternating

10 electric field induction type, an internal volumetric space of the sensor structure is almost occupied by the component parts of the drive mechanisms for driving the fork-shaped shutter or for vibrating the cantilever-like vibrating element, and others.

15 Accordingly, the size reduction of those drive mechanisms is essential for reducing the size of the electric potential sensor.

The current output as an output signal from the potential sensor of the mechanically modulated

20 alternating electric field induction type is obtained from the following equation based on the equations (1) and (2):

$$i = d[AVS/x]/dt... \quad (3)$$

As described above, with size reduction of the

25 electric potential sensor, the area S of the detection electrode becomes small. As a result, the sensor output current "i" also becomes small, and the

output signal from the sensor is easily influenced by external noise. The sensor is structured as an assembly of individual component parts. Thus, problem remains unsolved in terms of the size and cost

5   reduction.

DISCLOSURE OF THE INVENTION

Accordingly, with the view of overcoming the problems mentioned above, an object of the present

10 invention is to provide an electric potential measuring device, an image forming apparatus, and an electric potential measuring method, which are useful in realizing size reduction, high sensitivity and high reliability.

15   To achieve the above object, there is provided an electric potential measuring device including: an oscillating device which includes torsion springs, and an oscillating body axially supported by the torsion springs such that the oscillating body

20 oscillates about the torsion springs; and signal detecting means which is located on a surface of the oscillating body and includes at least one detection electrode, in which an output signal appearing on the detection electrode is detected by varying a distance

25 between the detection electrode and a surface of an electric potential measuring object disposed facing the detection electrode by the oscillating device to

vary a capacitance between the detection electrode and the surface of the electric potential measuring object. As understood from the related art description, to vary the capacitance between the

5   surface of the electric potential measuring object, such as a photosensitive drum, and an electric potential sensor (detection electrode) as the electric potential measuring device, any of the following (1) to (3) is varied: (1) distance between

10   the surface of the potential measuring object and the detection electrode, (2) dielectric constant of a material between them, and (3) facing area between them. In the present invention, the above-mentioned (1) is varied; the detection electrode is typically

15   provided on the periodically oscillating body, and control to vary the distance between the detection electrode and the surface of the electric potential measuring object is carried out. Such electric potential measuring device allows easy designing of a

20   configuration in which the oscillating body oscillates at a high frequency by appropriately selecting torsional rigidity of the torsion spring and a configuration of the oscillating body and others. Further, even if the oscillating body is

25   small, it is easy to achieve a configuration in which a plurality of detection electrodes are provided on the surface of the oscillating body, and signals

outputted from the electrodes are appropriately

processed (that is, design flexibility is high). With

those features, even if the electric potential

measuring device is small in size, an electric

5   potential on the surface of the electric potential

measuring object can be measured with relatively high

measuring accuracy, sensitivity, and reliability.

The invention based on the technical idea

mentioned above can be implemented in various modes.

10   In one mode, two detection electrodes are

disposed at positions on both sides across the

central axis about which the oscillating body

oscillates, on the surface of the oscillating body,

and output signals containing information of

15   different phases and amplitudes appear on the

detection electrodes. In another mode, the signal

detecting means performs a signal detection by use of

a difference between the two output signals outputted

from the detection electrodes. For example, a

20   plurality of electrodes are provided on the

oscillating body axially supported by means of

torsion springs such that those electrodes are line

symmetrical with respect to the oscillation central

line of the oscillating body, and are disposed facing

25   the electric potential measuring object. In this case,

distances between the detection electrodes on the

oscillating body and the electric potential measuring

object are alternately varied by periodically oscillating the oscillating body, whereby charges generated on the detection electrodes are alternately varied. By so doing, an electric potential sensor

5   which produces output signals that are configured to be suitable for a differential amplifier and timed as desired and are easy to be processed can be realized.

A surface of the oscillating body may be a planar surface, a convex spherical surface, a convex

10 cylindrical surface whose generating line is parallel to the oscillation central axis, a roofshaped surface whose edge line is parallel to the oscillation central axis, or the like. Curvatures of the spherical surface and the cylindrical surface, a

15 vertical angle of the roofshaped surface and the like may be designed depending on the oscillation angle of the oscillating body, the layout and the number of detection electrodes, required device size and sensitivity, and the like.

20   According to another aspect of the present invention, there is provided an image forming apparatus including the electric potential measuring device and image forming means, in which a surface of the oscillating body of the electric potential

25 measuring device is disposed facing a surface of an electric potential measuring object of the image forming means, and the image forming means controls

an image forming process by using the signal

detection result from the electric potential

measuring device. The image forming means may contain

a copying function, a printing function or a

5   facsimile function. The image forming means includes

a photosensitive drum that rotates about a

predetermined axis, and a potential on a surface of

the photosensitive drum is measured by using the

electric potential measuring device. Also in the

10   image forming apparatus, the advantageous features of

the electric potential measuring device is

efficiently utilized.

According to still another aspect of the present

invention, there is provided an electric potential

15   measuring method including the steps of: placing an

oscillating body having an electrode which oscillates

about a shaft and an electric potential measuring

object such that the electrode faces the electric

potential measuring object; and measuring a surface

20   electric potential of the electric potential

measuring object based on a capacitance between the

electric potential measuring object and the electrode,

by oscillating the oscillating body.

As described above, the output signal appearing

25   on the detection electrode is detected by varying the

distance between the detection electrode disposed on

the surface of the oscillating body and the surface

of the electric potential measuring object disposed facing the detection electrode by the oscillating body to vary the capacitance between the surface of the detection electrode and the surface of the

5 electric potential measuring object. Therefore, design flexibility is relatively high, and even if the electric potential measuring device is small in size, the potential on the surface of the measuring object can be measured with relatively high measuring

10 accuracy, sensitivity, and reliability. Specifically, the oscillating frequency, the area of the detection electrode, and the layout of the detection electrodes can flexibly be determined by appropriately selecting the rigidity of the torsion spring, the shape, length,

15 cross sectional area and others of the oscillating body axially supported by the torsion springs. Accordingly, the sensitivity, accuracy and reliability as required upon occasion are easily realized. Further, the oscillating body can be

20 driven at high frequency by utilization of the resonance frequency. Therefore, the device of high sensitivity is realized. Furthermore, the electrodes of the signal detecting means, the circuit and part of the drive device, and the oscillating body may be

25 unitarily formed. As a result, the electric potential measuring device being small in size and low in cost can easily be realized.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing a first embodiment of the present invention;

Fig. 2 is a cross sectional view showing a positional relationship between an electric potential sensor and a measuring object in the first embodiment of the present invention;

Figs. 3A, 3B and 3C each are a diagram useful in explaining positional relationships between related components and the measuring object when a oscillating body is oscillating in the first embodiment according to the present invention;

Fig. 4 is a diagram for explaining a mechanism for driving the electric potential sensor in the first embodiment according to the present invention;

Fig. 5 is an exploded view showing another embodiment of the present invention;

Fig. 6 is a cross sectional view showing the another embodiment according to the present invention;

Fig. 7 is a diagram showing a mechanism including a photosensitive drum and devices disposed therearound in an electrophotographic developing unit using an electric potential sensor constructed according to the present invention; and

Fig. 8 clearly illustrates an opening 101 of a supporting substrate shown in Fig. 1.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, embodiments of the present invention will be described in detail.

<First Embodiment>

5   A first embodiment of the present invention will first be described with reference to Figs. 1 (if necessary, Fig. 8 which clearly illustrates an opening 101 of a supporting substrate shown in Fig. 1.), 2, 3A to 3C, and 4.

10   Fig. 1 shows a construction of an electric potential sensor according to an embodiment of the present invention. An opening 101 is formed at a central part of a supporting substrate 100. A plate-like oscillating body 104 is supported by means of

15 two torsion springs 102 and 103 at a central part of the opening 101. The oscillating body 104 has a structure which is shaped to be line symmetrical with respect to a center line A - A' connecting the center lines of the torsion springs 102 and 103 as viewed in

20 their major axis direction.

Two plate-like detection electrodes 111 and 112 being of the same shape are located on one of the surfaces of the oscillating body 104, while being likewise disposed line-symmetrically with respect to

25 the center line A - A'. The detection electrodes 111 and 112 are respectively connected to electrode pads 115 and 116 formed on the supporting substrate 100 by

electrode wirings 113 and 114 formed on the torsion

spring 102. The electrode pads 115 and 116 are

respectively connected to a non-inverting input

contact 122 and an inverting input contact 121 of a

5   differential amplifier 120, which is located outside

the supporting substrate 100, by wirings 117 and 118.

In Fig. 2 showing a cross sectional view taken

on line 2 - 2 in Fig. 1, there is illustrated the

electric potential sensor shown in Fig. 1 in a state

10   that it is located to a surface 201 of a measuring

object. The measuring object is, for example, a

photosensitive drum. The drum is rotated about a

shaft extending in a horizontal direction in the

drawing or a shaft extending in a direction

15   orthogonal of a paper surface of the drawing. Where

the surface 201 of the measuring object, which faces

the oscillating body 104, is substantially planar,

the oscillating body 104 is disposed to be

substantially parallel to the surface when the

20   oscillating body is at a neutral position. In Fig. 2,

reference numeral 202 designates a case used for

accommodating the electric potential sensor therein.

The case is made of a conductive material, and

earthed. The supporting substrate 100 supporting the

25   oscillating body 104 is fastened to the case 202 by

appropriate mounting means 203 and 204. Because of

presence of the case 202, lines of electric force

emanating from only a portion of the surface 201,
which is directly opposite to the oscillating body
104, are allowed to reach the detection electrodes
111 and 112. As a result, the reduction of noise
5   components and the accurate potential measurement are
ensured.

The oscillating body 104 is periodically
oscillated about a central axis C of the torsion
springs 102 and 103 when an appropriate oscillating
10   body drive mechanism as will be described later is
additionally used for the electric potential sensor,
and the springs 102 and 103 are appropriately shaped
and made of an appropriate material.

Figs. 3A to 3C are each a cross sectional view
15   taken on line 2 - 2 in Fig. 1, and schematically
illustrate angular states of the oscillating body 104
when it is oscillated. Fig. 3A shows an angular state
of the oscillating body 104 when it is in a
stationary state or when it reaches, during its
20   oscillation, an angular position which is the same as
of the stationary state (In the specification, this
state of the oscillating body will be referred to as
a "neutral position"). Here, a distance between the
detection electrode 111 (112) and the measuring
25   object 201 is $x0$, and a distance from the central
axis line C of the oscillating body 104 to a central
point E of the detection electrode 111 when viewed in

the line 2 - 2 direction is L1, and a distance from the central axis line C of the oscillating body to a central point F of the detection electrode 112 when viewed in the same direction is L2.

Fig. 3B shows an angular state of the oscillating body 104 when it is turned and the distance between the detection electrode 111 and the measuring object 201 is the maximum. In this state, the oscillating body 104 is tilted at an angle $\theta 1$ to the left from the neural state of Fig. 3A. In the angular state of Fig. 3B, the distance x1max between the central point E of the detection electrode 111 and the measuring object 201 is given by the following equation:

$$x1max = x0 + L1 \cdot \sin (\theta 1) \ldots (4)$$

Also in this state, the minimum distance x2min between the central point F of the detection electrode 112 and the measuring object 201 is given by the following equation:

$$x2min = x0 - L2 \cdot \sin (\theta 1) \ldots (5)$$

Fig. 3C shows an angular state of the oscillating body 104 when it is turned and the distance between the detection electrode 111 and the measuring object 201 is the minimum. In this state, when the oscillating body 104 is tilted from the neutral state to the right at an angle $\theta 2$, the distance x1min between the measuring object 201 and

the central point E of the detection electrode 111 is given by

$$x1min = x0 - L1 \cdot \sin(\theta2) \; ... \; (6)$$

In this state, the maximum distance x2max between the central point F of the detection electrode 112 and the measuring object 201 is given by the following equation:

$$x2max = x0 + L2 \cdot \sin(\theta2) \; ... \; (7)$$

In this embodiment, a structure including the oscillating body 104 and the detection electrodes 111 and 112 is symmetrical with respect to the central axis line Ç. Therefore, the distances L1 and L2, and the tilting angles $\theta1$ and $\theta2$ may be related as follows: $L1 = L2$ and $\theta1 = \theta2$. If so related, the following equations hold:

$$x1max = x2max, \; and \; x1min = x2min \; ... \; (8)$$

The oscillating body 104 can be oscillated sinusoidally. When it is oscillating at an angular frequency ω, a distance x1(t) between the central point E of the detection electrode 111 and the measuring object surface 201 at a time point "t" is mathematically expressed by the following equation:

$$x1(t) = x0 + \Delta x \cdot \sin(\omega \cdot t) \; ... \; (9)$$

where $\Delta x = L1 \cdot \sin(\theta1)$.

A distance x2(t) between the central point F of the detection electrode 112 and the surface 201 of the measuring object at a time point "t" is

mathematically expressed by the following equation:

$$x2(t) = x0 + \Delta x \cdot \sin(\omega \cdot t + \pi)$$

$$= x0 - \Delta x \cdot \sin(\omega \cdot t) \ldots (10)$$

In the above equation, π is a phase delay expressed

in radian, and is equal to 180°.

An electric potential measuring method by using

the electric potential sensor will be described.

As thus far described, the distances between the

central points of the detection electrodes 111 and

112 installed on the oscillating body 104 and the

measuring object 201 located facing the oscillating

body 104, vary periodically as understood from the

equations (9) and (10). In the embodiment, the

structure including the oscillating body 104 and the

detection electrodes 111 and 112 is symmetrical with

respect to the central axis line C. Accordingly, a

distance between the measuring object 201 and the

detection electrode 111 may be represented by the

distance x1(t) from the measuring object 201 to the

central point E. A distance from the measuring object

201 to the detection electrode 112 may likewise be

represented by the distance x2(t) from the measuring

object 201 to the central point F.

The two detection electrodes 111 and 112

provided on the electric potential sensor shown in

Figs. 1 and 2 produce output signals i1(t) and i2(t),

respectively. Arranging the equations (3), (9) and

(10) gives those output signals i1(t) and i2(t) as below.

$$i1(t) = d/dt(C1(t) \cdot V) = d/dt[A \cdot V \cdot S/x1(t)]$$
$$= d/dt[A \cdot V \cdot S/(x0 + \Delta x \cdot sin(\omega \cdot t))] \ldots (11)$$
$$i2(t) = d/dt(C2(t) \cdot V) = d/dt[A \cdot V \cdot S/x2(t)]$$
$$= d/dt[A \cdot V \cdot S/(x0 + \Delta x \cdot sin(\omega \cdot t + \pi))]$$
$$= d/dt[A \cdot V \cdot S/(x0 - \Delta x \cdot sin(\omega \cdot t))]$$
$$= i1(t + \pi/\omega) \ldots (12)$$

where C1(t) is a capacitance between the detection electrode 111 and the measuring object 201, and C2(t) is a capacitance between the detection electrode 112 and the measuring object 201. In the above equations, i1(t) is an output signal current which is generated when charge caused by the capacitor formed between the detection electrode 111 and the measuring object 201 varies with time. i2(t) is an output signal current which is generated when charge caused by the capacitor formed between the detection electrode 112 and the measuring object 201 varies with time. S is an area of each of the detection electrodes 111 and 112. V is an electric potential of the measuring object 201. A is a proportional constant, which is the same as the proportional constant A used in the equation (2).

Therefore, the capacitance C1 between the measuring object 201 and the detection electrode 111 on the oscillating body 104 and the capacitance C2

between the measuring object 201 and the detection
electrode 112 on the oscillating body 104 are
sinusoidally varied when the oscillating body 104 is
sinusoidally oscillated at the angular frequency ω.

5   In this way, the electric potential sensor can
produce the separate signal currents i1(t) and i2(t)
which respectively includes information on the
surface potential V of the measuring object 201 and
which are phase shifted from each other by π (180°),

10   thereby the surface electric potential V of the
measuring object 201 can be detected.

A method of processing the signal currents i1(t)
and i2(t) derived from the electric potential sensor
will be described.

15   It is understood from the equations (11) and
(12) that the signal currents i1ω(t) and i2ω(t) =
i1ω(t + π/ω) can be derived from the detection
electrodes 111 and 112 by oscillating the oscillating
body 104 at a frequency f(ω = 2·π·f). The charge

20   amount Q in the equation (1) is generally an
extremely minute physical quantity, and the output
signal current "i", which is expressed by
differentiating it with respect to time, is also
minute. Accordingly, the signal currents i1ω(t) and

25   i2ω(t) are also minute signals. Those signals are
related as described above, and the signal current
i2ω(t) is equivalent to that obtained by shifting the

phase of i1ω(t) by 180°(π) (it is (1/2) period in
terms of time, as given by π/ω = 1/(2f)). A detecting
circuit, called a differential amplifier, is suitable
for processing such signals. Those signals i1ω(t) and
5   i2ω(t) are inputted to the differential amplifier to
amplify those signals so that the magnitudes of those
signals are two times as high as the original ones.
Further, noise which will adversely affect those
signals is removed after the signals are processed by
10   the amplifier.

A method for driving the oscillating body 104 in
the electric potential sensor will now be described.
Fig. 4 is a diagram useful in explaining a mechanism
for oscillating the oscillating body 104 in the
15   electric potential sensor. The oscillating body 104
and the supporting substrate 100, which are housed in
the case 202, are mounted to a piezoelectric element
401 by means of mounting means 203 and 204. Drive
power supply electrodes 402 and 403 are formed on the
20   piezoelectric element 401, and are connected to a
drive power supply 404.

When the oscillating body 104 is angularly moved
as shown in Fig. 3, it is oscillated (vibrated) at a
frequency, called a resonance frequency fc,
25   corresponding to its structure. This oscillation is
called a proper vibration mode of the oscillating
body 104. A drive signal whose frequency is equal to

the resonance frequency fc is applied from the drive power supply 404 to the electrodes 402 and 403, whereby the oscillating body 104 and the supporting substrate 100, which are stored in the case 202, are

5   vibrated at the frequency fc. The proper vibration mode of the oscillating body 104 couples with the oscillation at the frequency fc caused by the piezoelectric element 401, and the oscillating body oscillates at the resonance frequency fc.

10   In this way, the oscillating body 104 can be oscillated at its resonance frequency fc by use of the drive mechanism shown in Fig. 4.

A method of manufacturing the electric potential sensor which is the first embodiment of the present

15   invention will now be described. The electric potential sensors each having the structure shown in Fig. 1 can be manufactured in a mass production by processing a silicon substrate by using the micromachining technique. To be more specific, a

20   silicon substrate can be bored to form an opening 101 passing through the substrate per se by a processing technique, such as a dry etching process. A portion of the silicon substrate left after the etching process will be used for a supporting subsrate 100,

25   torsion springs 102 and 103, and a oscillating body 104.

By use of a film forming technique which is

generally used in the semiconductor manufacturing technique, an insulating film is formed over the surfaces of the supporting substrate 100, the torsion springs 102 and 103, and the oscillating body 104,

5   and further the detection electrode 111 and 112, and the detection electrode wirings 113 and 114 can also be formed.

Thus, those parts 100, 102 to 104, and 111 to 114 can be formed on a single substrate, not through

10   the assembling process. Further, the electric potential sensors can be manufactured in mass production by using a silicon substrate having a size large enough to allow a plurality of electric potential sensors of this embodiment to be formed

15   thereon.

In this embodiment, the structure including the oscillating body 104 and the detection electrodes 111 and 112 is symmetrical in shape with respect to the central axis line C. Even if one or both of them is

20   asymmetrical with respect to the central axis line, the useful effects comparable with those of this embodiment can be produced if some modification is made to the process for processing the output signals to properly process the output signals. It is evident

25   that this technical implementation also falls within the scope of the present invention. Alternatively, the invention can be implemented by using one

detection electrode and properly detecting one output
signal of it. In this case, the signal sensing
ability is somewhat lower than that of the above-
mentioned embodiment. In this alternative,

5   charge/discharge current based on the charge induced
in the detection electrode is detected in the form of
voltage by a detecting circuit. One of the methods of
detecting the current is a passive measuring method
which detects the current by utilizing a voltage drop

10   across a known resistor. Another method is a active
measuring method, for example, a zero-potential
method, which uses a potential adjusting element
circuit which adjusts the charge/discharge current
caused in the detection electrode so that it becomes

15   zero in level, through the adjustment of a potential
of the case 202 housing the electric potential sensor
shown in Fig. 2. Where the zero-potential method is
used, the case 202 is not earthed, but is connected
to an appropriate potential adjusting circuit.

20   Further, it is not essential that the surface of
the oscillating body is planar. A surface portion of
the oscillating body on which the detection
electrode(s) is located may be a convex spherical
surface, a roofshaped surface, a convex cylindrical

25   surface or the like, and the detection electrode is
provided thereon. Accordingly, a difference between
an amount of lines of electric force that the

detection electrode receives from the surface of the measuring object when the detection electrode is located near the surface of the measuring object and that when it is located apart from the object surface,

5   is increased. In this respect, the sensitivity performance of the electric potential sensor is enhanced.

<Another Embodiment>

In the electric potential sensor having the

10   oscillating body structure constructed according to the present invention, the method for driving the oscillating body is not limited to the above-mentioned one. Another embodiment of the invention will be described with reference to Figs. 5 and 6.

15   Fig. 5 is an exploded view showing an electric potential sensor which employs an oscillating body drive system, which is different from that in the first embodiment. Fig. 6 is a cross sectional view taken along a plane perpendicular to the torsional

20   central axis line C in Fig. 5. In the embodiment, a hard magnetic film 501 is formed on the surface of the oscillating body 104 on which the detection electrodes 111 and 112 are not formed such that different magnetic poles are formed at both ends of

25   the oscillating body 104, which are on both sides of the central axis line C of the torsion springs 102 and 103. A planar substrate 500 is disposed

substantially parallel to the surface of the

supporting substrate 100 for supporting the

oscillating body 104, which is opposite to the

surface thereof, which faces the surface of the

5   measuring object. An opening 502, which is

substantially the same in shape as the opening 101 of

the supporting substrate 100, is also formed in the

substrate 500. A planar coil 503 is wound around the

opening. The supporting substrate 100 is coupled to

10   the substrate 500, while a spacer 504 is interposed

therebetween.

In the electric potential sensor thus

constructed, when appropriate current is fed to the

planar coil 503, a magnetic field is generated in the

15   opening 502. A couple of forces whose direction is a

driving direction of the oscillating body 104 is

generated by utilizing the attracting and repelling

forces generated between the magnetic field and the

hard magnetic film 501 formed on the oscillating body

20   104.

A direction of a magnetic field developed by the

coil 503 is reversed when the direction of current

fed to the planar coil 503 is periodically changed,

and the direction of the couple of forces generated

25   on the oscillating body 104 changes. As a result, the

oscillating body 104 is oscillated. At this time,

when the direction of the current fed to the planar

coil 503 is alternately changed at a frequency equal to the resonance frequency fc of the oscillating body 104, the oscillating body 104 is oscillated in a resonant motion at the frequency fc. The remaining portion of this embodiment is the same as of the first embodiment.

Also in this embodiment, a structure including the oscillating body 104 can be manufactured from a single silicon substrate by the micromachining technique as in the first embodiment. Further, a plurality of sensor elements can collectively be formed on a single silicon substrate.

The same thing is true for the formation of the substrate 500 including the coil 503, viz., a plurality of elements can be manufactured on a single silicon substrate. It is readily understood that the manufacturing technique of the electric potential sensors is not limited to the micromachining technique referred to above.

The electric potential measuring device of the present invention can be applied to a system consisting of a plurality of devices (such as, a host computer, interface devices, an image reader, and printers) and also to a single device (such as a copying machine or a facsimile machine). Fig. 7 is a model diagram showing a mechanism including a photosensitive drum and devices disposed therearound

in an electrophotographic developing unit using an electric potential sensor constructed according to the present invention.

As shown, a charger 702, an electric potential sensor 701, an exposure device 705, and a toner supplying device 706 are disposed around a photosensitive drum 708. The charger 702 charges a surface of the photosensitive drum 708, and the exposure device 705 irradiates, for exposure, a surface of the photosensitive drum 708 with light to thereby form a latent image thereon. The toner supplying device 706 supplies toner onto the latent image to form a toner image. Further, the toner image is transferred onto a transferred material 709 to which a toner image is transferred, which is sandwiched between a roller 707 and the photosensitive drum 708, and the toner image transferred from the transferring material is fixed on the transferred material. Through those steps, an image is formed.

In this case, a charging state of the photosensitive drum 708 is measured by the electric potential sensor 701, signals are processed by a signal processor 703, and the charger 702 is controlled through a high voltage generator 704 in a feedback manner. As a result, a stable drum charging and a stable image formation are realized.